

Remarks

I. Status of claims

Claims 1-7, 9-13, and 15 were pending.

Claims 8, 14, and 16-20 have been withdrawn.

Dependent claim 21 has been added.

The features of independent claim 4 have been incorporated into independent claim 1.

Claim 4 has been canceled without prejudice.

II. Amendment of the Specification

The Specification has been amended to clarify the description by including a reference to one of the drawings.

III. Rejection of claims

The Examiner has rejected claims 1-7, 9-13, and 15 under 35 U.S.C. § 102(e) over Takayama (U.S. 6,329,676). In particular, the Examiner has asserted that:

Takayama discloses DH-LEDs composed of second and third or (n-type and p-type, respectively) GaN clads sandwiching an InGaN active layer (see, e.g., ABSTRACT, and col. 6, line 48 – col. 7, line 9). The InGaN active layer has a thickness set within 1 and 10 nm (e.g., FIG. 6 and col. 5, lines 65-). The clad thicknesses are each on the order of 2 μm (e.g., col. 7, lines 1-9), and therefore are wider than the polarization space charge regions that will necessarily be formed in each. As such, Takayama discloses a heterostructure that is capable of functioning as a tunnel junction, as claimed.

The attached Declaration, however, explains that the polarization fields in GaN/ $\text{In}_x\text{Ga}_{1-x}\text{N}$ /GaN structures that are configured as described in Takayama would not have magnitudes that are sufficient to align conduction band states at the Fermi level at the first heterointerface with valence band states at the Fermi level at the second heterointerface, as now recited in independent claim 1. Therefore, none of Takayama's LED embodiments inherently anticipates independent claim 1.

The Examiner has asserted that:

Regarding the dependent claim 2, Applicant acknowledges in the present specification that setting the intermediate layer to a thickness on the order of 10 nm or less enables charge carriers to tunnel with the current density claimed (see, e.g., page 5 of the Specification, second paragraph).

The Examiner, however, has misconstrued the teachings in the Specification. In particular, the section of the Specification cited by the Examiner merely indicates that "In some embodiments, intermediate semiconductor layer 16 has a thickness that is on the order of about 10 nm, or less." This statement does not apply to all of the embodiments described in the specification. Rather this statement applies only to some of the embodiments described in the Specification, including those embodiments in which "the polarization field magnitude (together with the dopant-induced drift field) may be insufficient to align an occupied conduction band state at the first heterointerface 18 with an unoccupied valence band state at the second heterointerface 20 at zero applied bias" (page 7, lines 27-30). Thus, there is no reasonable basis for the Examiner to conclude that this statement applies to the GaN/AlGaIn/GaN structured described in Takayama.

Applicant notes that one of ordinary skill in the art at the time of the invention would not have been motivated to modify any of Takayama's LED embodiments in such a way as to achieve a polarization field with a magnitude sufficient to align conduction band states at the Fermi level at the first heterointerface with valence band states at the Fermi level at the second heterointerface because such a modification would have defeated the object of Takayama's invention. In particular, Takayama explains that in a properly functioning device (col. 4, lines 41-44):

Passage of a current through the active layer causes carrier injection into the active layer which leads to emission of light of a first frequency, indicated at 30, when holes and electrons recombine.

Takayama additionally explains that "The objective is to induce carrier injection into the active layer" (col. 7, lines 12-13). If the polarization fields in Takayama's LEDs were sufficient to align conduction band states at the Fermi level at the first heterointerface with valence band states at the Fermi level at the second heterointerface, electrons would tunnel through the active layer. Consequently, electrons and holes would not recombine in the active layer and Takayama's LEDs would not generate any light whatsoever, defeating the

object of Takayama's invention. A modification that defeats the operability of Takayama's invention hardly would have been an obvious modification to one of ordinary skill in the art at the time of the invention.

For at least these reasons, the Examiner's rejection of independent claim 1 under 35 U.S.C. § 102(e) now should be withdrawn.

Claims 2-7, 9-13, and 15 incorporate the features of independent claim 1 and therefore are patentable for at least the same reasons.

IV. Conclusion

For the reasons explained above, all of the pending claims are now in condition for allowance and should be allowed.

Charge any excess fees or apply any credits to Deposit Account No. 50-1078.

Respectfully submitted,

Date: July 9, 2004



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Mark R. Hueschen Art Unit : 2815
Serial No. : 10/071,439 Examiner : Baumeister, Bradley W.
Filed : February 8, 2002
Title : POLARIZATION FIELD ENHANCED TUNNEL STRUCTURES

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 CFR § 1.132

I, Mark R. Hueschen, hereby declare as follows.

1. I am the sole inventor of the subject matter recited in the pending claims of the above-identified patent application, as amended by the Amendment filed herewith.
2. I am a senior scientist at Agilent Technologies.
3. In my capacity as a senior scientist, I work on advanced semiconductor devices, and novel electronic devices.
4. I have been working in the field of GaN-based optoelectronic devices for over 4 years.
5. The following analysis is based on an LED that includes a heterostructure formed from an $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region sandwiched between a pair of oppositely doped GaN cladding regions, where the subscript 0.05 is the mole fraction of indium. The active region is configured to emit light at a wavelength of 450 nm, which implies that the active region bandgap is approximately 2.8 eV. The dielectric constant of the $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region is assumed to be approximately 10.

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450 on:

July 9, 2004

Date



(Signature of person mailing papers)

Edouard Garcia

(Typed or printed name of person mailing papers)

- a. The polarization sheet charge produced at each of the $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}/\text{GaN}$ and $\text{GaN}/\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ heterointerfaces in the heterostructure of ¶ 5 is approximately $4 \times 10^{12} \text{ cm}^{-2}$.
- b. The polarization sheet charge of ¶ 5a produces an electric field of approximately $7 \times 10^5 \text{ V/cm}$.
- c. The polarization offset voltage is given by the product of the electric field of ¶ 5b and the thickness of the $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region.
 - i. For an $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region thickness of 20 \AA , the polarization offset voltage is approximately 0.14 eV .
 - ii. For an $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region thickness of 45 \AA , the polarization offset voltage is approximately 0.32 eV .
 - iii. For an $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region thickness of 100 \AA , the polarization offset voltage is approximately 0.70 eV .

6. In the above analysis, the largest polarization offset voltage (i.e., 0.70 eV) is exhibited by an $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ active region with a thickness of 100 \AA . This polarization offset voltage is only 25 % of the 2.8 eV bandgap of the active region. Accordingly, the polarization field for the heterostructure example of ¶ 5c(iii) is insufficient to align conduction band states at the Fermi level at the first $\text{GaN}/\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$ heterointerface with valence band states at the Fermi level at the second $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}/\text{GaN}$ heterointerface.

7. The statement in ¶ 6 regarding the insufficiency of the polarization field to align states across the active region is true even assuming the active region and cladding layers in the heterostructure of ¶ 5c(iii) are doped at typical, nondegenerate doping levels for an LED based on such a heterostructure, including up to $2 \times 10^{18} \text{ atoms cm}^{-3}$ for n-type doping and $1 \times 10^{18} \text{ atoms cm}^{-3}$ for p-type doping.

8. I declare that all statements made herein of my own knowledge are true and that all statements made on declaration and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the

Applicant : Mark R. Hueschen
Serial No. : 10/071,439
Filed : February 8, 2002
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United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

Date: 7/9/04

Mark Hueschen
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